US008457818B2

(12) **United States Patent**
Itano et al.

(10) **Patent No.:** **US 8,457,818 B2**
(45) **Date of Patent:** **Jun. 4, 2013**

(54) **TRAIN SLIDE CONTROL DEVICE AND TRAIN SLIDE CONTROL METHOD**

(75) Inventors: **Yasuharu Itano**, Chiyoda-ku (JP);
Hiroshi Yamada, Chiyoda-ku (JP);
Etsuji Matsuyama, Chiyoda-ku (JP)

(73) Assignee: **Mitsubishi Electric Corporation**,
Chiyoda-Ku, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 273 days.

(21) Appl. No.: **12/937,124**

(22) PCT Filed: **May 8, 2009**

(86) PCT No.: **PCT/JP2009/058700**
§ 371 (c)(1),
(2), (4) Date: **Oct. 8, 2010**

(87) PCT Pub. No.: **WO2009/154048**
PCT Pub. Date: **Dec. 23, 2009**

(65) **Prior Publication Data**
US 2011/0029167 A1   Feb. 3, 2011

(30) **Foreign Application Priority Data**

Jun. 20, 2008   (WO) PCT/JP2008/061336

(51) **Int. Cl.**
B60T 8/1766   (2006.01)
B61H 13/30   (2006.01)
(52) **U.S. Cl.**
USPC **701/20**; 701/78; 701/79; 303/22.6;
303/128
(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,316,640	A	*	2/1982	Cripe	303/20
5,654,889	A	*	8/1997	Wood et al.	701/71
2002/0088673	A1	*	7/2002	Malac	188/1.11 R

FOREIGN PATENT DOCUMENTS

DE	2625962	*	12/1977
JP	60-045454	A	3/1985
JP	63-008061		1/1988
JP	05-319243		12/1993
JP	06-054406		2/1994

(Continued)

OTHER PUBLICATIONS

Office Action dated Mar. 1, 2011, issued in the corresponding Japanese Patent Application No. 2010-517813, and an English Translation thereof.

(Continued)

Primary Examiner — Michael J Zanelli
(74) *Attorney, Agent, or Firm* — Buchanan Ingersoll & Rooney PC

(57) **ABSTRACT**

A train slide control device and a train slide control method capable of further improving the precision of slide control are achieved. The train slide control device comprises: an electromagnetic valve unit; a relay valve that outputs a pressure of the brake cylinder; and a slide controller that includes: a velocity-difference detecting unit that detects a velocity difference of each wheel based on a velocity signal; a deceleration calculating unit that calculates a deceleration of a train based on the velocity signal; a sliding-amount determining unit that determines a sliding-amount of each wheel based on the velocity difference and deceleration; and a brake-cylinder-pressure calculating unit that calculates a pressure control signal for controlling a pressure of the brake cylinder based on:
the sliding-amount; a brake command for obtaining a predetermined deceleration; and a signal that indicates the pressure of the compressed air and a pressure of the brake cylinder.

14 Claims, 4 Drawing Sheets
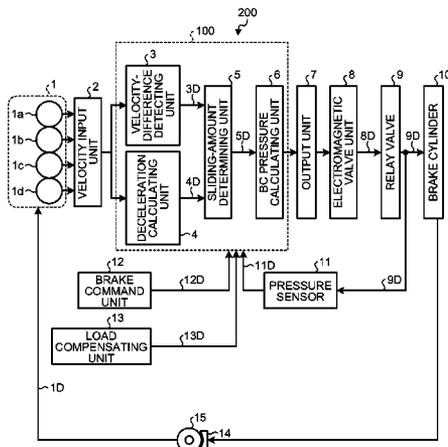
FOREIGN PATENT DOCUMENTS

JP	6-54406	*	2/1994
JP	7-096826	A	4/1995
JP	8-214407	A	8/1996
JP	10-217929		8/1998
JP	11-235972	A	8/1999
JP	2000-211487	A	8/2000
JP	2001-219839	A	8/2001
JP	2003-063366		3/2003
JP	2004-306865	A	11/2004
JP	2004-336958		11/2004

OTHER PUBLICATIONS

Office Action (Decision of a Patent Grant) dated Jun. 28, 2011, issued in the corresponding Japanese Patent Application No. 2010-517813, and an English Translation thereof.

International Search Report (PCT/ISA/210) issued on Aug. 18, 2009, by Japanese Patent Office as the International Searching Authority for International Application No. PCT/JP2009/058700.

Written Opinion (PCT/ISA/237) issued on Aug. 18, 2009, by Japanese Patent Office as the International Searching Authority for International Application No. PCT/JP2009/058700.

Office Action from Chinese Patent Office dated Jan. 14, 2013, issued in corresponding Chinese Patent Application No. 200980118460.1, and English translation thereof.
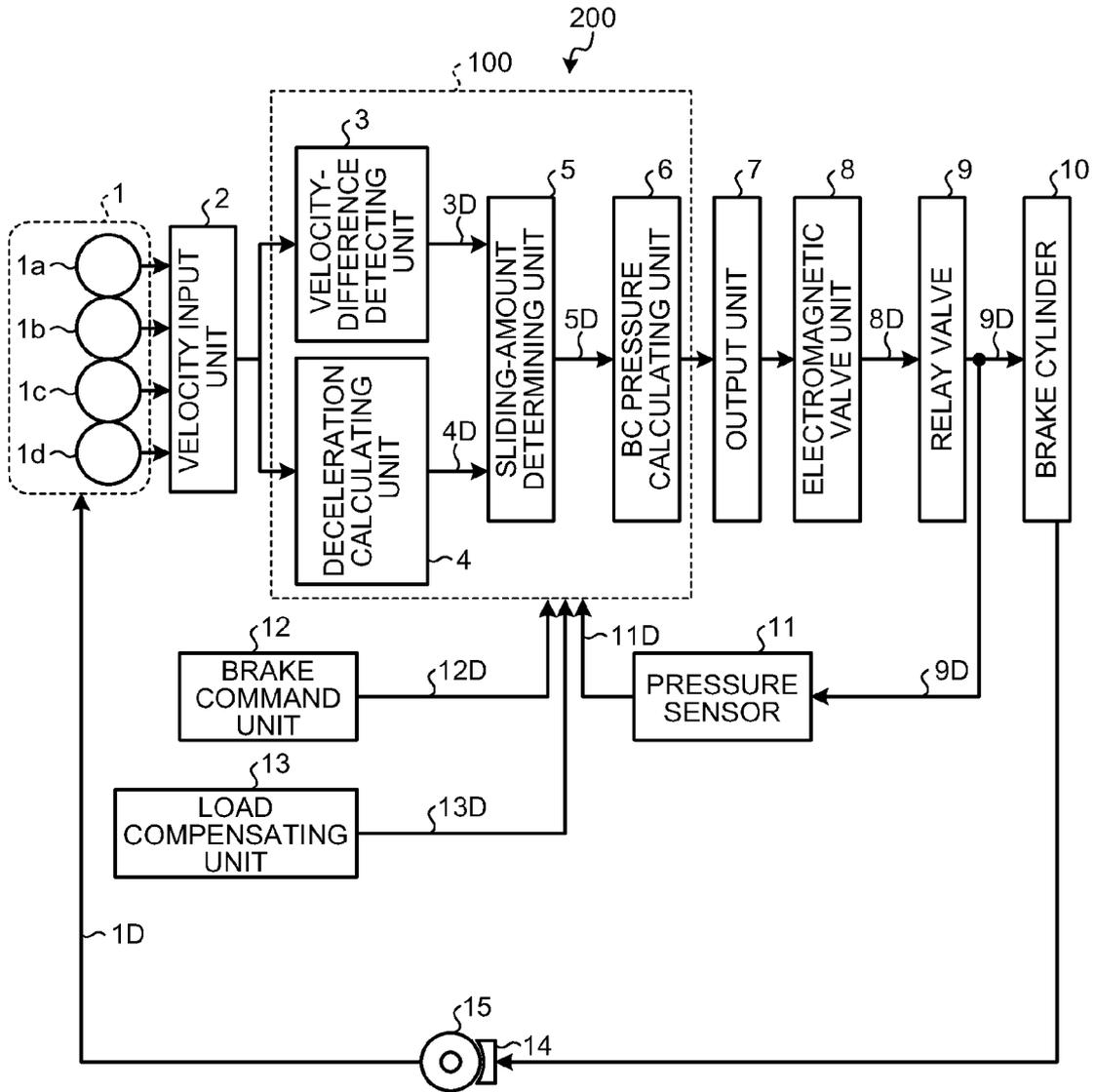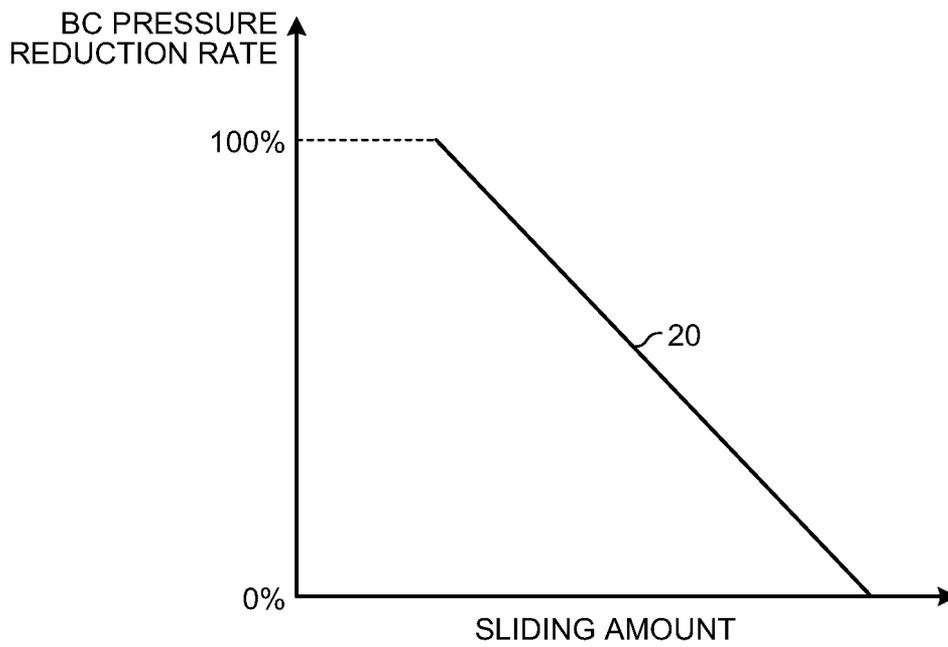
* cited by examiner

FIG.1

FIG.2

BC PRESSURE
REDUCTION RATE

100%

20

0%

SLIDING AMOUNT

FIG.3

30

NUMBER OF SLIDES	FIRST TIME	SECOND TIME	THIRD TIME
BC PRESSURE REDUCTION RATE	20%	30%	40%

FIG.4

START

S1 IS BRAKE COMMAND RECEIVED? — NO

YES

S2 CALCULATE DECELERATION AND VELOCITY DIFFERENCE

S3 HAS SLIDE OCCURRED? — NO

YES

S4 CALCULATE SLIDING AMOUNT

S5 CALCULATE TARGET BC PRESSURE

S6 FEED BACK BC PRESSURE TO BC PRESSURE CALCULATING UNIT

S7 HAS CURRENT BC PRESSURE APPROXIMATED TARGET BC PRESSURE? — NO
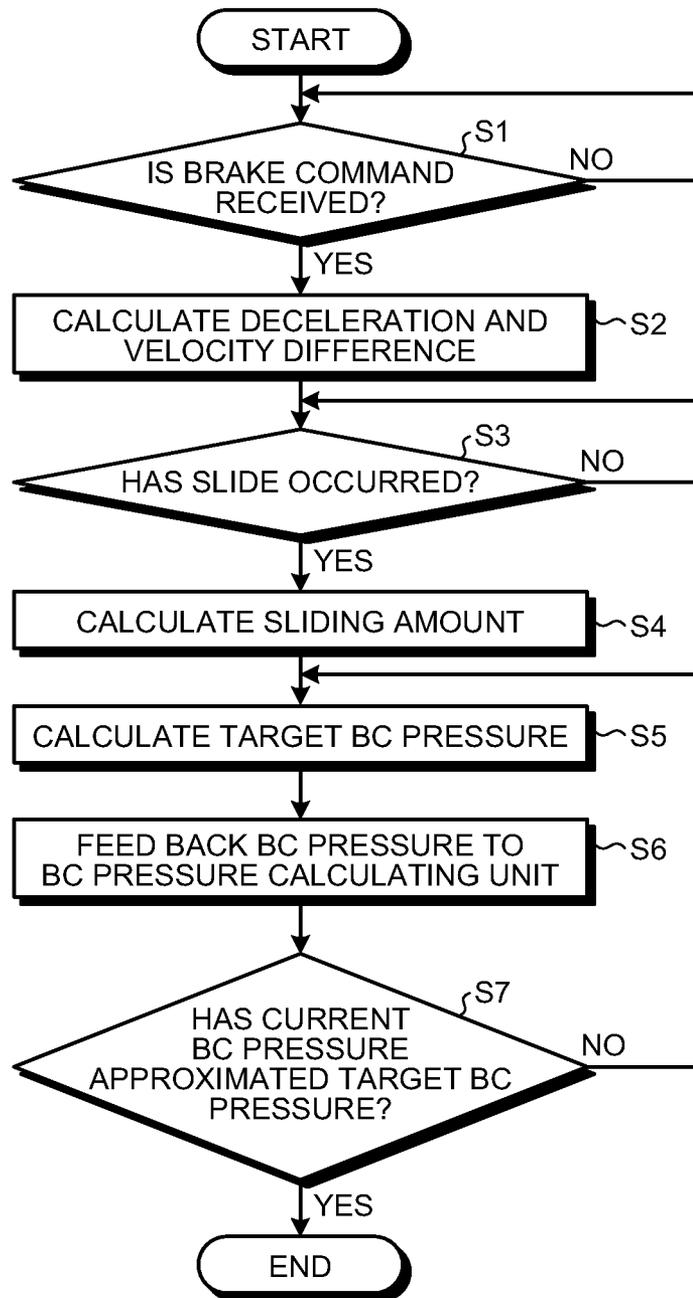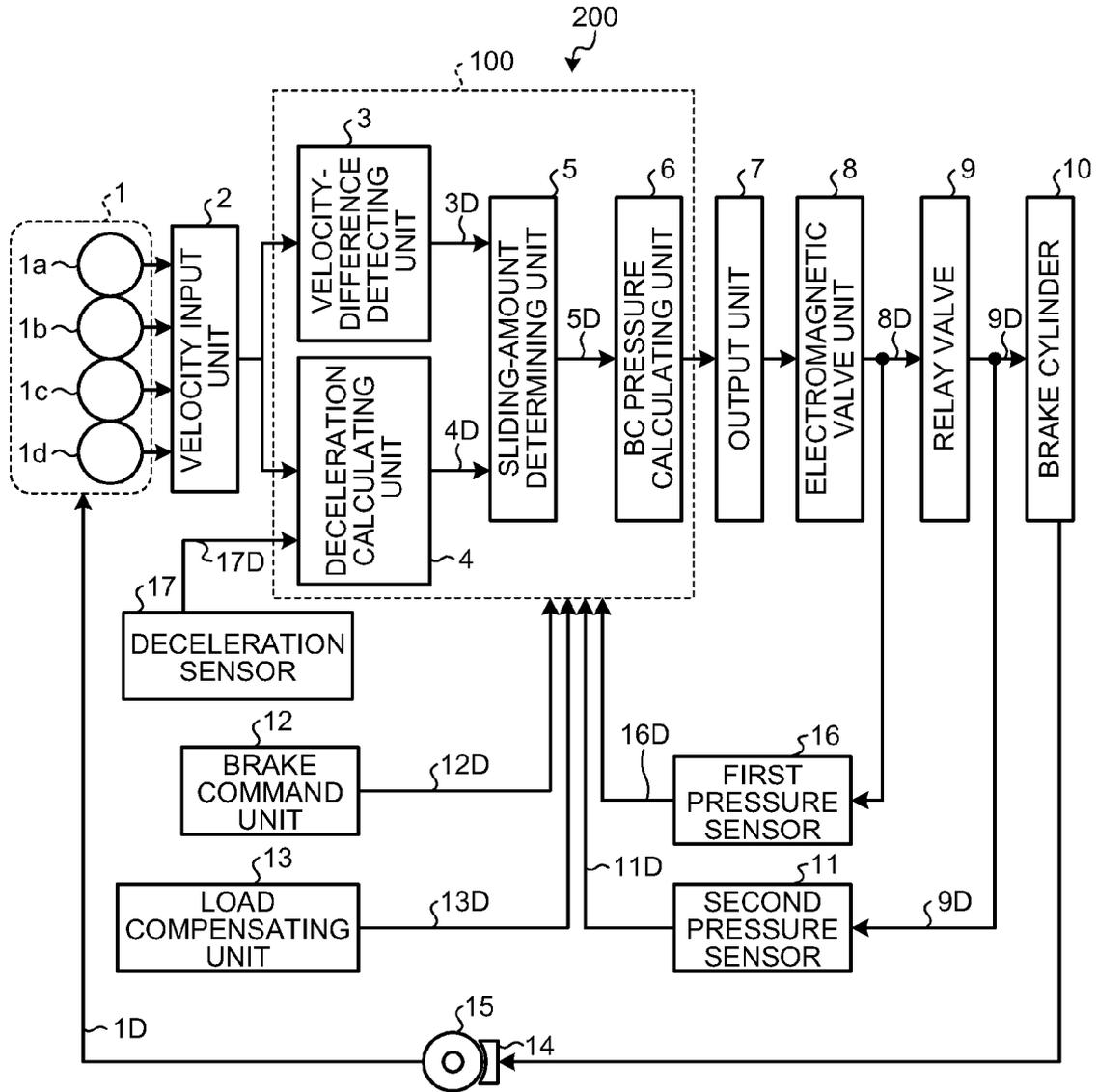
YES

END

FIG.5

TRAIN SLIDE CONTROL DEVICE AND TRAIN SLIDE CONTROL METHOD

TECHNICAL FIELD

The present invention relates to a train slide control device and a train slide control method that detect a slide of a wheel while a brake is operated to control a brake force.

BACKGROUND ART

Conventionally, for example, a train slide control device described in Patent Document 1 is configured such that a velocity sensor detects the number of revolutions of each wheel, and when a difference is generated between the number of revolutions of one wheel and the number of revolutions of other wheels while a brake is operated, compressed air supplied to a brake cylinder of a sliding wheel is exhausted or supplied to increase or decrease a brake cylinder pressure for preventing a slide. The brake cylinder pressure is provided by amplifying compressed air outputted according to opening and closing operations of electromagnetic valves for regular use brake control and slide control (hereinafter, "electromagnetic valve unit") by a relay valve.

Patent Document 1: Japanese Patent Application Laid-open No. 2004-306865

DISCLOSURE OF INVENTION

Problem to be Solved by the Invention

However, according to the train slide control device described in Patent Document 1, a volume of compressed air is large in the relay valve and thus hunting (an unstable state because of a control amount varying near a target value) occurs. Accordingly, the state of the brake cylinder pressure cannot be utilized for slide control. Therefore, slide control considering a variation in the brake cylinder pressure cannot be performed and thus further improvement in the precision of slide control is difficult.

The present invention has been achieved in view of the above circumstances, and an object of the present invention is to provide a train slide control device and a train slide control method capable of further improving the precision of slide control.

Means for Solving Problem

To solve the above problems and achieve the object, a train slide control device includes: an electromagnetic valve unit having a supply valve that supplies supplied compressed air to a brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air; a relay valve that outputs a pressure of the brake cylinder according to the compressed air supplied from the electromagnetic valve unit; and a slide controller that includes: a velocity-difference detecting unit configured to detect a velocity difference of each wheel based on a velocity signal; a deceleration calculating unit configured to calculate a deceleration of a train based on the velocity signal; a sliding-amount determining unit configured to determine a sliding-amount of each wheel based on the velocity difference and deceleration; and a brake-cylinder-pressure calculating unit configured to calculate a pressure control signal for controlling a pressure of the brake cylinder based on: the sliding-amount; a brake command for obtaining a

predetermined deceleration; and a signal that indicates the pressure of the compressed air and pressure of the brake cylinder.

According to the present invention, the precision of slide control can be further improved.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an example of a configuration of a train slide control device according to a first embodiment.

FIG. 2 is an example of a BC-pressure reduction-rate pattern.

FIG. 3 is an example of a BC-pressure reduction-rate table.

FIG. 4 is a flowchart of an example of a flow of determining a brake cylinder pressure.

FIG. 5 is an example of a configuration of a train slide control device according to a third embodiment.

EXPLANATIONS OF LETTERS OR NUMERALS

1, 1a, 1b, 1c, 1d Velocity sensor
1D Velocity signal
2 Velocity input unit
3 Velocity-difference detecting unit
3D Velocity difference
4 Deceleration calculating unit
4D Deceleration
5 Sliding-amount determining unit
5D Sliding amount
6 Brake-cylinder-pressure calculating unit
7 Output unit
8 Electromagnetic valve unit for regular use brake control and slide control
8D Pressure control signal
9 Relay valve
9D Signal indicating brake cylinder pressure
10 Brake cylinder
11, 16 Pressure sensor
11D, 16D Feedback command
12 Brake command unit
12D Brake command
13 Load compensating unit
13D Load compensation signal
14 Brake shoe
15 Wheel
17 Deceleration sensor
17D Deceleration sensor output
20 BC-pressure reduction-rate pattern
30 BC-pressure reduction-rate table
100 Slide control unit
200 Train slide control device
F Brake force

BEST MODE(S) FOR CARRYING OUT THE INVENTION

Exemplary embodiments of a train slide control device according to the present invention will be explained below in detail with reference to the accompanying drawings. The present invention is not limited to the embodiments.

First Embodiment

FIG. 1 is an example of a configuration of a train slide control device according to a first embodiment. A train slide control device 200 shown in FIG. 1 includes, as its main constituent elements, a velocity sensor 1, a slide control unit

100, an output unit **7**, an electromagnetic valve unit **8** for regular use brake control and slide control (hereinafter, "electromagnetic valve unit"), a relay valve **9**, a brake cylinder **10**, a pressure sensor **11**, a brake command unit **12**, a load compensating unit **13**, a brake shoe **14**, and a wheel **15**.

The velocity sensor **1** is arranged at front and rear carriages of each vehicle (four in total) and fetches a velocity signal **1D** of each wheel **15**. A velocity input unit **2** fetches the velocity signal **1D** from velocity sensors **1a** to **1d** of each vehicle.

The slide control unit **100** includes the velocity input unit **2**, a velocity-difference detecting unit **3**, a deceleration calculating unit **4**, a sliding-amount determining unit **5**, and a brake-cylinder-pressure (BC pressure) calculating unit **6**. The velocity-difference detecting unit **3** detects a velocity difference **3D** between the wheel **15** that is not sliding and another wheel **15** that is sliding. The deceleration calculating unit **4** differentiates the velocity signal **1D** received from the velocity sensors **1a** to **1d** to detect deceleration **4D** of a train. The deceleration calculating unit **4** may be an embodiment of being capable of detecting both "acceleration" and "deceleration" or an embodiment of being capable of detecting only one of the "acceleration" and "deceleration".

The sliding-amount determining unit **5** determines that a slide has occurred when outputs of the velocity-difference detecting unit **3** and the deceleration calculating unit **4** exceed predetermined values set in advance and outputs a sliding amount **5D**. The above mentioned predetermined values may be set arbitrary.

The load compensating unit **13** is provided at each carriage, detects a weight of the front and rear carriages for every vehicle, and outputs a load compensation signal **13D** corresponding to a change in load during braking (a load of the front carriage in a traveling direction of a train is larger than that of the rear carriage). For example, when a brake command **12D** is outputted, the load compensating unit **13** mounted on the front carriage in the traveling direction (a first load compensating unit) outputs a load compensation signal corresponding to a vehicle weight acting on the corresponding carriage (a first load compensation signal). When the brake command **12D** is outputted, the load compensating unit **13** mounted on the rear carriage in a traveling direction of a train (a second load compensating unit) outputs a load compensation signal corresponding to a vehicle weight acting on the corresponding carriage (a second load compensation signal).

When the brake command **12D** is outputted from the brake command unit **12** or the load compensation signal **13D** is outputted from the load compensating unit **13**, the brake-cylinder-pressure calculating unit **6** calculates a pressure control signal **8D** based on the sliding amount **5D** outputted from the sliding-amount determining unit **5** and controls the electromagnetic valve unit **8** of the sliding wheel **15** to control re-adhesion of the sliding wheel **15**. While the brake-cylinder-pressure calculating unit **6** is mentioned as an example of a unit that fetches the brake command **12D** or the load compensation signal **13D**, the present invention is not limited thereto.

For example, when a slide occurs in the rear carriage in the traveling direction of a train in one vehicle, the slide control unit **100** calculates a slide control value corresponding to the second load compensation signal **13D** described above and the pressure control signal **8D** obtained using the first load compensation signal **13D** and the sliding amount **5D**. The slide control unit **100** adds the slide control value corresponding to the second load compensation signal **13D** to the pressure control signal **8D** corresponding to the first load compensation signal **13D**. As a result, not only a signal **9D**

indicating a brake cylinder pressure of the sliding wheel **15** of the rear carriage (hereinafter, simply "brake cylinder pressure") may be reduced and the wheel **15** may be re-adhered, but also the brake cylinder pressure **9D** of the wheel **15** of the front carriage that is not sliding may be increased and a brake force may be used effectively in the entire vehicle.

The brake command unit **12** outputs the brake command **12D** for obtaining predetermined deceleration. The output unit **7** outputs a control signal outputted from the brake-cylinder-pressure calculating unit **6** to the electromagnetic valve unit **8**.

The electromagnetic valve unit **8** includes a supply valve that supplies supplied compressed air to the brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air and converts a control signal outputted from the brake-cylinder-pressure calculating unit **6** into compressed air of a predetermined pressure (the pressure control signal **8D**). The electromagnetic valve unit **8** exhausts or supplies the compressed air to be supplied to the relay valve **9** according to a slide state of the wheel **15**. For example, when the wheel **15** slides, the compressed air supplied to the relay valve **9** is exhausted, so that the brake cylinder pressure **9D** may be reduced and thus the wheel **15** may be re-adhered.

The relay valve **9** amplifies the pressure control signal **8D**, supplied from the electromagnetic valve unit **8**, to a predetermined pressure. An original air tank (not shown) is connected to the relay valve **9**. Because the compressed air is reserved in the original air tank, the relay valve **9** amplifies the pressure control signal **8D** to generate a brake cylinder pressure **9D** for driving the brake cylinder **10**.

The pressure sensor **11** detects the brake cylinder pressure **9D** (or the pressure control signal **8D**), generates a feedback command **11D** based on the brake cylinder pressure **9D** (or the pressure control signal **8D**), and feeds back the feedback command **11D** to the brake-cylinder-pressure calculating unit **6**. Although the brake-cylinder-pressure calculating unit **6** is mentioned as an example of a unit that fetches the brake cylinder pressure **9D** (or the pressure control signal **8D**), the present invention is not limited thereto.

The brake cylinder **10** presses the brake shoe **14** according to a magnitude of the brake cylinder pressure **9D**. The brake cylinder pressure **9D** may be calculated by a formula $B=F/(k*f)$ (B: brake cylinder pressure **9D**, F: brake force, k: constant, f: friction coefficient of the brake shoe **14**). When the friction coefficient is fixed, a brake force acting on the brake shoe **14** varies in proportion to the value of the brake cylinder pressure **9D**.

The relay valve **9** is shared by the front and rear carriages in conventional train slide control devices. That is, because the brake cylinder pressure **9D** of each vehicle is controlled by the relay valve **9**, an air quantity in the relay valve **9** is increased and thus the probability that hunting occurs is high. When the hunting occurs, the compressed air supplied to the relay valve **9** is not similar to the compressed air outputted from the relay valve **9** and a response of the brake cylinder pressure **9D** is inferior. Accordingly, when the brake cylinder pressure **9D** is fed back to the brake-cylinder-pressure calculating unit **6** via the pressure sensor **11**, an accurate pressure control signal **8D** is hard to be obtained.

In the train slide control device **200** according to the first embodiment, the relay valve **9** is made compact and disposed adjacent to each of the carriages. An air capacity within the relay valve **9** is reduced as compared to conventional cases. By correcting hysteresis of the relay valve **9** using the pressure sensor **11**, the relay valve **9** may be adjusted finely to have a predetermined pressure. Hunting is thus reduced and the response of the brake cylinder pressure **9D** is improved.

The slide control unit **100** uses the brake-cylinder-pressure calculating unit **6** as well as the velocity signal **1**D to generate the brake cylinder pressure **9**D.

The slide control unit **100** may use three modes, which are a "supply" mode, a "maintaining" mode, and a "release" mode for feedback control. In the "supply" mode, compressed air may be supplied. In the "maintaining" mode, supply and exhaust of the compressed air are stopped and a service brake may be maintained at a certain state. In the "release" mode, the compressed air may be exhausted.

FIG. **2** is an example of a BC-pressure reduction-rate pattern. A BC-pressure reduction-rate pattern **20** indicated by a solid line and a broken line is set in the brake-cylinder-pressure calculating unit **6** in advance for continuously deriving a BC-pressure reduction rate corresponding to the sliding amount **5**D outputted by the sliding-amount determining unit **5**. For example, when a slide occurs, the sliding-amount determining unit **5** calculates the sliding amount **5**D. The brake-cylinder-pressure calculating unit **6** refers to the BC-pressure reduction-rate pattern **20** for the sliding amount **5**D. Thus the brake-cylinder-pressure calculating unit **6** calculates the BC-pressure reduction rate corresponding to the sliding amount **5**D.

Further, the brake-cylinder-pressure calculating unit **6** derives "BC pressure reduction" corresponding to the BC-pressure reduction rate, subtracts "reduction of the BC pressure **9**D (the pressure control signal **8**D)" from "current BC pressure **9**D (the pressure control signal **8**D)" to calculate "target (re-adhesion) BC pressure **9**D (the pressure control signal **8**D)".

Because the train slide control device **200** can feed back the BC pressure **9**D to the brake-cylinder-pressure calculating unit **6**, the BC pressure **9**D may be repeatedly calculated to approximate the target BC pressure **9**D. The electromagnetic valve unit **8** may be operated continuously according to the repeatedly calculated BC pressure **9**D. The BC-pressure reduction-rate pattern **20** is not limited to the pattern illustrated in FIG. **2** (a slope of the linear solid line). The BC-pressure reduction-rate pattern **20** may be set for every brake shoe **14**.

FIG. **4** is a flowchart of an example of a flow of determining a brake cylinder pressure. The velocity-difference detecting unit **3** or the deceleration calculating unit **4** receives the velocity signal **1**D from the velocity sensors **1**a to **1**d and calculates the velocity difference **3**D of each wheel **15**. When the brake-cylinder-pressure calculating unit **6** receives the brake command **12**D (YES at Step S**1**), the velocity-difference detecting unit **3** and the deceleration calculating unit **4** calculate the velocity difference **3**D and the deceleration **4**D, respectively (Step S**2**). When the sliding-amount determining unit **5** determines that a slide has occurred (YES at Step S**3**), the sliding-amount determining unit **5** calculates the sliding amount **5**D (Step S**4**) and outputs the calculated sliding amount **5**D to the brake-cylinder-pressure calculating unit **6**. The brake-cylinder-pressure calculating unit **6** calculates the target BC pressure **9**D based on the sliding amount **5**D transmitted from the sliding-amount determining unit **5** (Step S**5**). The pressure sensor **11** feeds back the BC pressure **9**D to the brake-cylinder-pressure calculating unit **6** (Step S**6**). The brake-cylinder-pressure calculating unit **6** terminates slide control when the current BC pressure **9**D has approximated the target BC pressure **9**D (YES at Step S**7**).

When the brake-cylinder-pressure calculating unit **6** does not receive the brake command **12**D (NO at Step S**1**), the velocity-difference detecting unit **3** and the deceleration calculating unit **4** calculate neither the velocity difference **3**D nor the deceleration **4**D. When a slide has not occurred (NO at

Step S**3**), the sliding-amount determining unit **5** does not calculate the sliding amount **5**D.

When the current BC pressure **9**D (the pressure control signal **8**D) does not approximate the target BC pressure **9**D (the pressure control signal **8**D) (NO at Step S**7**), the brake-cylinder-pressure calculating unit **6** repeats processes subsequent to Step S**5** until the current BC pressure **9**D approximates the target BC pressure **9**D (the pressure control signal **8**D) and continues the slide control.

As described above, according to the train slide control device **200** of the first embodiment, the relay valve **9** is disposed adjacent to a carriage and the brake cylinder pressure **9**D (or the pressure control signal **8**D) with reduced hunting is fed back to the brake-cylinder-pressure calculating unit **6**. A time lag between the velocity difference **3**D of each wheel **15** is detected, as a basic brake is operated, and the slide control is performed is thus eliminated and the response of a brake force may be improved. Because the slide control may be continuously performed using the BC-pressure reduction-rate pattern **20**, re-slide may be reduced and an extension of a braking distance may be prevented as compared to the conventional train slide control devices. Further, because re-slide is reduced, generation of wheel flat on each wheel **15** (a flat spot generated when the wheel **15** is locked) is reduced and the man-hour for cutting the wheel **15**, noises and vibrations when a train travels, and deterioration in riding comfortability may be suppressed. Because cutting of the wheel **15** is reduced, the longevity of the wheel **15** may be extended. Further, when the brake cylinder pressure **9**D continues to be "0" during feedback control, the electromagnetic valve unit **8** is forced to be in a release or supply state. Futile operations of the electromagnetic valve unit **8** are thus eliminated and the longevity of the electromagnetic valve unit **8** may be extended.

Second Embodiment

The train slide control device **200** according to a second embodiment is configured so as to calculate a BC-pressure reduction rate for the wheel **15** according to the number of slides of the wheel **15**. Because a configuration of the train slide control device **200** and a flow of determining the brake cylinder pressure **9**D are identical to those illustrated in FIGS. **1** and **4** in the first embodiment, descriptions thereof will be omitted.

FIG. **3** is an example of a BC-pressure reduction-rate table. A BC-pressure reduction-rate table **30** illustrated in FIG. **3** is constituted by an item indicating the number of slides of the wheel **15** and an item indicating the BC-pressure reduction rate.

Although the first to third numbers of slides are indicated as an example of the number of slides in the item of the number of slides, the present invention is not limited thereto and the number of slides may be four or more, for example. Values of the BC-pressure reduction rate corresponding to the respective numbers of slides are indicated in the item of the BC-pressure reduction rate. For example, when a first slide occurs, the BC-pressure reduction rate is set to 20% and thus the brake-cylinder-pressure calculating unit **6** provides "reduction of the BC pressure **9**D" corresponding to "20%" of the BC-pressure reduction rate and subtracts this "reduction of the BC pressure **9**D" from the "current BC pressure **9**D". Values of the BC-pressure reduction rate are merely an example and the present invention is not limited thereto. The BC-pressure reduction rate may be set arbitrary. For example,

a step of the BC-pressure reduction rate may be set more finely. The BC-pressure reduction-rate table **30** may be set for every brake shoe **14**.

Because the train slide control device **200** can feed back the BC pressure **9D** (the pressure control signal **8D**) to the brake-cylinder-pressure calculating unit **6**, when a second slide occurs, the BC pressure **9D** may be calculated again. That is, the number of slides is incremented until the slide of the wheel **15** does not occur and the calculation mentioned above may be repeatedly performed. The slide control may be performed by combining the BC-pressure reduction-rate pattern **20** according to the first embodiment and the BC-pressure reduction-rate table **30**.

As described above, the train slide control device **200** according to the second embodiment can perform the slide control continuously by using the BC-pressure reduction-rate table **30**. Accordingly, as compared to conventional train slide control devices, re-slide may be reduced and extension of a braking distance may be prevented according to the second embodiment. Further, because re-slide may be reduced, generation of flat wheel of each wheel **15** is reduced and the man-hour for cutting the wheel **15**, noises and vibrations while a train travels, and a deterioration in riding comfortability may be suppressed. Because the man-hour for cutting of the wheel **15** is reduced, the longevity of the wheel **15** may be extended. Further, when the brake cylinder pressure **9D** continues to be "0" during feedback control, the electromagnetic valve unit **8** is forced to be in a release or supply state. As a result, futile operations of the electromagnetic valve unit **8** are eliminated and the longevity of the electromagnetic valve unit **8** may be extended.

Third Embodiment

A train slide control device according to a third embodiment is configured so as to correct maximum deceleration by deceleration calculated based on a deceleration sensor and feed back a feedback command generated based on a pressure control signal to a brake-cylinder-pressure calculating unit that further improves the precision of slide control. Parts identical to those in the first and second embodiments are denoted with like reference numerals and descriptions thereof will be omitted.

FIG. **5** is an example of a configuration of the train slide control device according to the third embodiment. The train slide control device **200** illustrated in FIG. **5** includes a deceleration sensor **17** and a first pressure sensor **16** in addition to the constituent elements of the train slide control device illustrated in FIG. **1**.

The deceleration calculating unit **4** calculates deceleration of a vehicle based on a deceleration sensor output **17D**. Further, the deceleration calculating unit **4** further corrects maximum deceleration by using the calculated deceleration as positive. This correction is effective for correction when all axes slide. The sliding-amount determining unit **5** determines that a slide has occurred when the corrected deceleration **4D** exceeds a predetermined value set in advance and outputs the sliding amount **5D**. The brake-cylinder-pressure calculating unit **6** calculates the pressure control signal **8D** based on the sliding amount **5D** when the brake command **12D** is outputted from the brake command unit **12** or the load compensation signal **13D** is outputted from the load compensating unit **13**, and the brake-cylinder-pressure calculating unit **6** controls the electromagnetic valve unit **8** of the sliding wheel **15**.

The first pressure sensor **16** detects the signal (the pressure control signal) **8D** that indicates a pressure of compressed air which is outputted from the electromagnetic valve unit **8**. The

first pressure sensor **16** generates a feedback command **16D** based on the pressure control signal **8D**, and feeds back the feedback command **16D** to the brake-cylinder-pressure calculating unit **6**. Although the brake-cylinder-pressure calculating unit **6** is illustrated as a place to which the pressure control signal **8D** is fed back, the present invention is not limited thereto.

As described above, in the conventional train slide control devices, the probability that hunting occurs is high. When hunting occurs, an accurate pressure control signal **8D** is hardly calculated even when the brake cylinder pressure **9D** is fed back to the brake-cylinder-pressure calculating unit **6** via the first pressure sensor **16** because the response of the brake cylinder pressure **9D** is inferior.

Similarly to the first embodiment, the train slide control device **200** according to the third embodiment is configured such that the relay valve **9** is made compact and the relay valve **9** is disposed adjacent to each carriage. The air capacity within the relay valve **9** is thus reduced as compared to the conventional cases. By correcting hysteresis of the relay valve **9** using the first pressure sensor **16**, the relay valve is finely adjusted to a predetermined pressure. As described above, three modes are used in the slide control unit **100**. For deceleration that is one of the conditions for switching the three modes, the deceleration **4D** corrected by the deceleration sensor **17** is used.

An operation of the train slide control device **200** according to the third embodiment is described below with reference to FIG. **4** described above. The velocity-difference detecting unit **3** or the deceleration calculating unit **4** receives the velocity signal **1D** from the velocity sensors **1a** to **1d** and calculates the velocity difference **3D** and the like of each wheel **15**. When the brake-cylinder-pressure calculating unit **6** receives the brake command **12D** (YES at Step S1), the velocity-difference detecting unit **3** and the deceleration calculating unit **4** calculate the velocity difference **3D** and the deceleration **4D**, respectively (Step S2). When the sliding-amount determining unit **5** determines that a slide has occurred (YES at Step S3), the sliding-amount determining unit **5** calculates the sliding amount **5D** (Step S4) and outputs the sliding amount **5D** to the brake-cylinder-pressure calculating unit **6**. The brake-cylinder-pressure calculating unit **6** calculates the target BC pressure **9D** based on the sliding amount **5D** transmitted from the sliding-amount determining unit **5** (Step S5). The second pressure sensor **11** feeds back the BC pressure **9D** to the brake-cylinder-pressure calculating unit **6** and the first pressure sensor **16** feeds back the pressure control signal **8D** to the brake-cylinder-pressure calculating unit **6** (Step S6). The brake-cylinder-pressure calculating unit **6** terminates slide control when the current BC pressure **9D** approximates the target BC pressure **9D** (YES at Step S7). As conditions for resetting the slide control, the velocity difference **3D** and the deceleration **4D** corrected by the deceleration sensor **17** are used.

When the current BC pressure **9D** does not approximate the target BC pressure **9D** (NO at Step S7), the brake-cylinder-pressure calculating unit **6** repeats processes subsequent to Step S5 until the current BC pressure **9D** approximates the target BC pressure **9D** and continues the slide control.

As described above, the train slide control device **200** according to the third embodiment includes the deceleration sensor **17** and the first pressure sensor **16**.

The deceleration calculating unit **4** corrects the maximum deceleration by using deceleration calculated based on the deceleration sensor **17D** as positive. The first pressure sensor **16** feeds back the feedback command **16D** generated based on the pressure control signal **8D** to the brake-cylinder-pres-

sure calculating unit **6**, and thus the precision of the slide control may be improved. As a result, reduction of re-slide and prevention of extension of a braking distance may be further expected.

INDUSTRIAL APPLICABILITY

As described above, the train slide control device according to the present invention is useful as a train slide control device that adjusts a brake cylinder pressure to perform slide control of each wheel.

The invention claimed is:

1. A train slide control device comprising:

a slide control unit configured to control an electromagnetic valve unit and a relay valve;

the electromagnetic valve unit having a supply valve that supplies supplied compressed air, through the relay valve, to a brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air;

the relay valve is configured to output a pressure of the brake cylinder according to the compressed air supplied from the electromagnetic valve unit; and

the slide control unit includes:

a velocity-difference detecting unit configured to detect a velocity difference of each wheel of a train, based on a velocity signal;

a deceleration calculating unit configured to calculate a deceleration of the train based on the velocity signal;

a sliding-amount determining unit configured to determine a sliding-amount of each wheel of the train based on the velocity difference and deceleration; and

a brake-cylinder-pressure calculating unit configured to calculate a pressure control signal for controlling a pressure of the brake cylinder based on:

the sliding-amount;

a brake command for obtaining a predetermined deceleration; and

a signal that indicates the pressure of the compressed air and pressure of the brake cylinder.

2. The train slide control device according to claim **1**, wherein, when a slide has occurred, the slide control unit calculates the pressure control signal by using a value of a pressure of the brake cylinder as a re-adhesion value based on a signal indicating a pressure of the brake cylinder outputted from the relay valve.

3. The train slide control device according to claim **2**, further comprising:

a first load compensating unit that is mounted on a front carriage in a traveling direction of a train and outputs a first load compensation signal corresponding to a train vehicle weight; and

a second load compensating unit that is mounted on a rear carriage in a traveling direction of a train and outputs a second load compensation signal corresponding to a train vehicle weight, wherein

when a slide has occurred in the rear carriage, the slide control unit adds a slide control value calculated by the second load compensation signal and the sliding amount to the pressure control signal corresponding to the first load compensation signal.

4. The train slide control device according to claim **1**, further comprising:

a first load compensating unit that is mounted on a front carriage in a traveling direction of a train and outputs a first load compensation signal corresponding to a train vehicle weight; and

a second load compensating unit that is mounted on a rear carriage in a traveling direction of a train and outputs a second load compensation signal corresponding to a vehicle weight, wherein

when a slide has occurred in the rear carriage, the slide control unit adds a slide control value calculated by the second load compensation signal and the sliding amount to the pressure control signal corresponding to the first load compensation signal.

5. A train slide control device comprising:

a slide control unit configured to control an electromagnetic valve unit and a relay valve;

the electromagnetic valve unit having a supply valve that supplies supplied compressed air, through the relay valve, to a brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air;

the relay valve is configured to output a pressure of the brake cylinder according to the compressed air supplied from the electromagnetic valve unit;

a deceleration sensor configured to detect a deceleration of a train; and

the slide control unit includes:

a velocity-difference detecting unit configured to detect a velocity difference of each wheel of a train based on a velocity signal;

a deceleration calculating unit configured to calculate the deceleration of the train based on the velocity signal;

a sliding-amount determining unit configured to determine a sliding-amount of each wheel of the train based on the velocity difference and the deceleration; and

a brake-cylinder-pressure calculating unit configured to calculate a pressure control signal based on the sliding-amount.

6. The train slide control device according to claim **5**, wherein a brake-cylinder-pressure calculating unit calculates the pressure control signal based on the sliding amount, a brake command, a pressure of the compressed air, and a signal indicating the pressure of the brake cylinder.

7. The train slide control device according to claim **6**, further comprising:

a first load compensating unit that is mounted on a front carriage in a traveling direction of a train and outputs a first load compensation signal corresponding to a train vehicle weight; and

a second load compensating unit that is mounted on a rear carriage in a traveling direction of a train and outputs a second load compensation signal corresponding to a train vehicle weight, wherein

when a slide has occurred in the rear carriage, the slide control unit adds a slide control value calculated by the second load compensation signal and the sliding amount to the pressure control signal corresponding to the first load compensation signal.

8. The train slide control device according to claim **5**, wherein, when a slide has occurred, the slide control unit calculates the pressure control signal by using a value of a pressure of the brake cylinder as a re-adhesion value based on a signal indicating a pressure of the brake cylinder outputted from the relay valve.

9. The train slide control device according to claim **8**, further comprising:

a first load compensating unit that is mounted on a front carriage in a traveling direction of a train and outputs a first load compensation signal corresponding to a train vehicle weight; and

a second load compensating unit that is mounted on a rear carriage in a traveling direction of a train and outputs a second load compensation signal corresponding to a train vehicle weight, wherein

when a slide has occurred in the rear carriage, the slide control unit adds a slide control value calculated by the second load compensation signal and the sliding amount to the pressure control signal corresponding to the first load compensation signal.

10. The train slide control device according to claim **5**, further comprising:

a first load compensating unit that is mounted on a front carriage in a traveling direction of a train and outputs a first load compensation signal corresponding to a train vehicle weight; and

a second load compensating unit that is mounted on a rear carriage in a traveling direction of a train and outputs a second load compensation signal corresponding to a train vehicle weight, wherein

when a slide has occurred in the rear carriage, the slide control unit adds a slide control value calculated by the second load compensation signal and the sliding amount to the pressure control signal corresponding to the first load compensation signal.

11. A train slide control method applicable to a train slide control device including an electromagnetic valve unit having a supply valve that supplies supplied compressed air to a brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air, and a relay valve that outputs a pressure of the brake cylinder according to the compressed air supplied from the electromagnetic valve unit, the train slide control method comprising:

a detecting step of detecting a velocity difference of each wheel of a train and deceleration of the train based on a velocity signal of each wheel of the train;

a first calculating step of calculating a sliding amount of each wheel of the train based on the velocity difference and the deceleration; and

a second calculating step of calculating a pressure control signal based on the sliding amount, a brake command for obtaining predetermined deceleration, and a signal indicating a pressure of the brake cylinder.

12. The train slide control method according to claim **11**, wherein at the second calculating step, the pressure control signal is calculated by determining a value of a pressure of the brake cylinder as a re-adhesion value using the signal indicating the pressure of the brake cylinder.

13. A train slide control method applicable to a train slide control device including an electromagnetic valve unit having a supply valve that supplies supplied compressed air to a brake cylinder and an exhaust valve that adjusts a pressure of the supplied compressed air, a relay valve that outputs a pressure of the brake cylinder according to the compressed air supplied from the electromagnetic valve unit, and a deceleration sensor that detects deceleration of a train, the train slide control method comprising;

a detecting step of detecting a velocity difference of each wheel of a train and a deceleration of the train based on a velocity signal of each wheel of the train and an output of the deceleration sensor;

a first calculating step of calculating a sliding amount of each wheel of the train based on the velocity difference and the deceleration; and

a second calculating step of calculating a pressure control signal based on the sliding amount, a brake command for obtaining predetermined deceleration, a signal that is outputted from the electromagnetic valve unit and indicates a pressure of the compressed air, and a signal indicating a pressure of the brake cylinder.

14. The train slide control method according to claim **13**, wherein at the second calculating step, the pressure control signal is calculated by determining a value of a pressure of the brake cylinder as a re-adhesion value using the signal indicating the pressure of the brake cylinder.

* * * * *